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ABSTRACT

Prepared for a 1984 Organisation for Economic Cooperation and Development (OECD) conference, this report focuses on issues and problems identified by research on the impact of the new information technologies on learning processes in formal education at the elementary and secondary levels. The impact of the new technologies is discussed in the context of the chronological, contextual, and topical organization of learning. The implications of these technologies for pedagogical approaches are discussed together with ways in which institutional systems could accommodate the changes in educational practices that would result from the application of the "new generation" of pedagogical approaches, which would reflect the move away from broad general theories to the development of specific approaches adapted to specific learning and specific learners. A discussion of some of the ways in which the issue of learning and the new technologies can be approached to establish working agendas for the future includes some likely alternatives, the work priorities that could emerge, and ways in which these could be met. It is argued that separate approaches could be developed on similar learning issues that would reflect the interests of cognitive science, the educational institution, and social and economic concerns. Criteria that could be used to select within approaches are then suggested, and the likely consequences of the integration of the new information technologies in education are discussed. A three-page bibliography concludes the document. (MBR)

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International Conference on Education and New Information Technologies

Château de la Muette
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THE IMPACT OF THE NEW INFORMATION TECHNOLOGIES ON LEARNING PROCESSES IN FORMAL EDUCATION

The attached document, prepared by the Secretariat, will serve as a background report for Working Group 2.

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"Organisation is a universal property of organic matter. Life as we understand it is only an evolved form of that organisation." (H. Reeves, 1981)

"Human reason is a product of biological organisation, a refined, superior product of course, but ultimately just one product like any other". (J. Piaget, 1975)

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INTRODUCTION

"The nature of the new information technologies is not the electronics, but the formal language, the rules and methods that are set to present reality to computers and the programmes utilised to make them function. It is this invisible aspect of the technologies that makes them important in different contexts."
(I. Ruoppila, 1983)

"Culture is being lost from view in a welter of products, in an avalanche of signs, in senseless quantity." (M. Kundera, 1984)

1. This report covers one of the areas under investigation in the CERI project on "Education and New Information Technologies" [CERI/CD/(81)15], as it was approved by the CERI Governing Board in November 1981. Its objective is to clarify the main issues and problems on the impact of the new information technologies (NIT) on learning processes in formal education. While anchored on cognitive grounds, this report addresses a readership other than that of specialists in the cognitive sciences. It addresses educational experts, practitioners and administrators, who are increasingly involved in making decisions as to the planning of investments, the development of curricula and of innovative teaching/learning strategies in a technologically modified environment. This "educational" slant affects the whole of the report, it biases the selection of "cognitive" issues, it influences the terminology used, more familiar to educators.

2. As its title indicates, this report is concerned with learning processes in the school. Its data basis covers information gathered in research and educational experimentation on the development of learning that is, or might be, relevant to the world of schools, in both primary and secondary education. Its mandate is not to propose a synthesis of all the available literature in the area but, less ambitiously, to clarify the main constituents in the current debate on learning and the new information technologies on the basis of an indicative body of experimental results.

3. This "down to earth" approach has given a concrete rather than speculative grounds to the analysis. It has also narrowed the discussions to the consideration of those issues and problems which happen to have been the object of investigation. It will be easy for the reader to spot the topics that, although important to education agendas, receive here only a cursory treatment or are altogether absent from the text. Such omissions should not

be taken as indicating possible priority shifts in future education agendas. They merely denote that the place of these issues in the "technological" programmes of work is, just for the time being, peripheral.

4. In addition to narrowing the selection of topics, this report's preoccupation of being concrete rather than speculative has also resulted in a much narrower definition of the technologies considered. The bulk of data available on "information technologies" and learning processes relate almost exclusively to computers and especially to micro or mini computers. This is the current bias in the "technological" working agendas. This is, unavoidably, also a bias of this report.

5. On more conceptual grounds, a further characteristic of the analysis presented here is to rest on a central assumption on the nature of learning and of the forces and factors shaping it. The assumption says that learning does not take place in a vacuum, that the process of learning depends on more than just the nature of what is to be learned and the ability of the learner to perform. When absorbing new concepts or mastering unfamiliar skills any individual is also reacting to a multitude of other actors and factors -- visible or invisible, silent or vocal -- all influencing, manipulating, encouraging, discouraging, hampering or fostering the growth of the capital of knowledge in the learner.

6. Any analysis of learning processes, any intervention intended to develop or modify them by altering their human and technological environment, cannot but acknowledge the existence of these "other" active agents. As well as to the learners, it is to these active agents that the processes are adjusted, it is with them -- or against them -- that the learning can possibly be changed, by way of the new information technologies or otherwise. These agents are not difficult to recognise: they influence the life-long learning whereby the child grows into an adult, whereby individual life-patterns are constructed for work, leisure, family and social life, until the end. These agents are as tangible as the family, the school, the peer group, the work place, or as vaguely perceivable as the networks of powers and concerns surfacing through cultural and educational policies, through the information channels or more generally, which shape the life conditions (social, economic and political) whereby an individual can learn. In short, and this is what it is important to underline here, learning processes unfold to the learner under a number of influences, from within and from without, conditioning to various degrees what is learned, how and to what purpose.

7. The new information technologies do not eliminate the dependence of actual learning on factors other than the learner's aptitude to learn. But the question deserves to be asked whether they can shuffle their relative influence, whether they can change the patterns of influences, whether they can introduce new conditioners. The issue is therefore raised in this report of whether, together with any specific effect on the learning aptitudes as such, the new information technologies, by acting as a vehicle of influence, or by generating some of their own, can change what is learned, how and to what purpose.

8. As a response to the perceived potential influence of the new information technologies on learning, the current debate has sometimes taken on cultural and philosophical overtones, exemplified by a much-voiced concern: will the new "technological" power released by man to his benefit

lose control and turn against him? In terms of learning processes, this "existential" pre-occupation questions the degree of distortion introduced by the technologies in the representation of the world or of the man-built knowledge transmitted by them on to the learner. In each case the attention is called on the consequences for the learner of emphasizing the growth of logical patterns, of privileging the acquisition of cognitive skills, that risk reflecting more the specific nature of the electronics underneath than the overall possibilities of the human brain. In short, by defining themselves as alternative gateways to the acquisition of knowledge and skills, the technologies are presenting mankind with the possibility of new sources of influence on what is learned, how and to what purpose.

9. Perhaps the largest potential held by the new information technologies is in terms of quantity: they can increase beyond imagination the amount of information accessible to the ordinary people, by increasing the possibilities of storage, transmission, diffusion and retrieval. Perhaps the single most important challenge this creates for learning is in terms of quality: how can any single citizen learn to manage this new possibility? Our society is already information rich. Already learning processes are conditioned by information flooding the homes, the workplace, the school, the community. What to expect if the amount of information increases yet further, if its degree of coherence, already small, decreases even further. No doubt such issues will fuel a number of policy debates in the future, in a variety of policy sectors.

10. In education, this debate on the quality of learning can be seen as touching directly upon two aspects of its institutional mandate: the chronological organisation of learning -- essentially a question of curriculum -- and its management on pedagogical grounds.

11. In terms of timing, some of the (interrelated) questions raised more often in the curriculum area concern its targetting to the age of the pupil, its sequential organisation and the speed at which specific knowledge and skills can be acquired. Most of the curricula, especially in basic education, are designed on the basis of some developmental assumptions on the cognitive abilities of the pupil: certain notions and certain skills -- e.g. concrete or formal -- cannot be acquired before a certain age. Another widespread assumption sees learning as essentially a cumulative process where notions and skills are acquired through a carefully balanced sequence of steps from simple to complex. To what extent will these assumptions survive the impact of the technologies, to what extent will they be invalidated, transformed, expanded by them? Section I of this report will discuss in some detail some of the answers which start emerging, primarily from the area of research on cognitive psychology and artificial intelligence. The important point to anticipate here is that far from being theoretical and beside their vested interest (the survival of the institution in its current form is one of the implicit stakes to this debate) questions such as these point to possibilities that are real and already visible in a number of specific educational instances.

12. Next to concerns more directly "cognitive", the debate in education develops along lines with a more specific institutional bearing. The new information technologies, by increasing access to information and by changing the definition of knowledge and skills, can have an impact on the definition of disciplines as such, and hence, together with the (possible) impact on the cognitive performance of the pupils, can alter the curricular boundaries

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Section I

LEARNING PROCESSES

"Using computers (could) challenge current beliefs about who can understand what and at what age... Using computers (could) question standard assumptions in developmental psychology and in the psychology of aptitudes and attitudes" (S. Papert, 1980)

"One day the computer broke down because she had no children to teach. The children came back and put a bandage on her screen. The computer felt better and began teaching again. The class lived happily every after." (A primary school pupil, USA, Collins, 1983)

17. With this section we enter the core of the debate on the impact of the new information technologies on learning processes in formal education. Those in charge of designing, planning and managing educational programmes put forward specific questions as to if, when and in what conditions, the NIT are likely to have an impact on the learning processes induced in the various population groups present in the school. They need to know what the changes are, if any, in the "quality" of the learning taking place in the modified conditions. They ask whether the array of abilities learned or knowledge acquired via the NIT differ in any considerable way from what is obtained within "traditional" educational environments. In particular, they are concerned with the possible changes that the NIT can introduce in the organisation, structure and management of the formal educational system with respect to the age structure of their population and the articulation of the various disciplines and courses of study.

18. Questions of this kind are both pertinent and unequivocal. This and the subsequent sections, attempt to answer them, by taking the analysis from its starting point, the cognitive processes, and developing it by considering the possible pedagogical applications of the new knowledge and understanding on learning emerging from research and experimentation work. In the next section, the analysis will be developed further by considering the ways whereby the most promising pedagogical approaches could be brought to bear on current educational practices in view of a large scale introduction of the NIT into schools.

19. To establish an analytical structure for a discussion on learning

processes and the NIT in formal education, means to operate on a selection of issues which, possibly contrary to expectations, is, for the time being, rather limited. Although each large and complex in itself, the three areas do not share a large number of issues. The relationship between learning as a set of psychological processes and learning as the pedagogical management of them has been historically tenuous. Of the large ground covered by each, there is little that could be identified as common to both. The part of it which is also relevant to the NIT, whose bearing on the previous two is only just developing, can be but smaller still.

20. Therefore, more than the result of a reasoned choice among likely alternatives, the analytical structure proposed in this section is rather one of convenience. This structure does not reflect the existence of a large enough body of data (not produced as yet) nor does it emerge from sound theoretical models as to their possible significance (still being developed). If this section has a value, it is of a highly pragmatic kind. It develops a tentative analytical framework which allows a reasonable discussion of the issues at stake without pushing the speculation too far. In addition, it allows a discussion of typically theoretical and experimental issues on grounds familiar to those for whom this report is ultimately written: those in charge of schools and of educational policies.

21. For these people, asking questions on the possible impact of the NIT on learning processes in formal education means essentially to assess its implications in terms of three broad issues, each related in important ways to the organisation of the institutional system. The first is the chronological organisation of learning. In which ways do the NIT alter the speed at which pupils usually learn? How do they change the age targetting of institutionalised learning? What is their impact on its traditionally sequential organisation? The second is the contextual organisation of learning. As in other instances, school learning involves interactions with humans as well as with learning tools. In which ways do the NIT alter such a context of learning? With what effects? What if the NIT replace the teachers? What if they limit the social interactions with the peer group? How are the technologies percieved by the young learners? The third is the topical organisation of learning. How could the knowledge and skills taught at school be modified by the NIT? What becomes of the basic skills? What new skills have to be learned? What cognitive prerequisites are needed by what new learning? What is the transfer value, what are its cognitive consequences?

THE TIME DIMENSION OF LEARNING

22. A first topic to consider under this heading is model-free, as it were. In a variety of circumstances, at different levels of schooling and in different learning situations, it has been observed that, when learning is computer-based, the learning itself is accelerated. A typical finding says that students have been found to learn more, retain more or learn the same amount faster using computers (e.g. Bracey, 1982).

23. Besides (rare) quantitative confirmations by bodies such as the California Testing Service, the wealth of evidence put forward to sustain the claim, remains unmatched by the reliability and validity of the observations.

What exist most in this area are teachers' reports. When computers are introduced in classroom teaching, it is not unusual to have reports of pupils covering the year curriculum in much less time, to the extent of creating some perturbation in the organisation of the classroom. A Canadian teacher comments on the situation: "Some of the bright children are now wanting time alone on the machine. Maybe they are looking to escape into it and ignore other things...I am giving them some lone time but they are having to come back and teach the rest of the group. I feel that I must stop them from getting too far ahead, for then, they tend to say that the other kids do not understand. This way they are bringing the group along with them" (Burnett et al., 1983)

24. At times the gain in time is expressed by a general feeling of "easiness". Examples could be found at the intermediate schooling levels, where, for instance, a teacher has reported on a LOGO experience, that "using co-ordinates on the computer made the learning of latitude and longitude in geography easy" (Burnet et al., 1983). From the same report, a grade 6/7 teacher writes: "I have taught all the Grade 6 geometry and gone beyond the curriculum to the Grade 8 level of angles. When I was teaching a lesson on lines, points and vertices the children said they already knew it. This is a result of working with the computer... I feel my class is ready for recursion in understanding although they did not have the maths concepts yet".

25. At other times, the findings are of a more concrete nature. A recent report, for instance, states that at the post-secondary level, "in every study in which computer-based instruction substituted for conventional teaching (either for a unit, a module, or for an entire course), the computer did its job quickly -- on average in about two-thirds the time required by conventional methods. It is clear that the computer can function satisfactorily in college courses and at the same time reduce time spent in instruction". (Kulik et al, 1980)

26. Although far from scientific soundness, the anecdotal evidence is particularly compelling in the case of remedial learning. In a number of cases, the low achievers, the school failures have been observed to learn, at least in the basic skills, in a relatively short time where years of traditional teaching/learning situations had failed to produce any noticeable results (e.g. Naymark, 1983).

27. Faced with such an increasingly suggestive body of evidence, a first, rather basic, question arises as to its possible meaning: do the NIT produce qualitatively different learning processes or do they just change the persepctive with which we observe what are essentially the same processes and mechanisms as in "machine-free" learning environments? Do the NIT sollicit the development of new brain functions or are they merely eliciting a different organisation of otherwise familiar human functions?

28. It can very well be, for instance, that the NIT shorten the time spent to learn simply by way of rationalising the learning situation. There is no doubt, for instance, that most ordinary learning processes in the classroom are rather wasteful in terms of time. One could easily imagine how the NIT could hasten them by eliminating hollow periods, by keeping the learner active and motivated, by presenting the information in ways that are easier to assimilate. It can also be that the new technologies bring to the awareness of the learner elements which are important to the learning and which would

otherwise go unnoticed. In the words of a French author, describing the possible reasons at the root of observed performances in learning Logo, "the computer's capabilities are likely to modify the pattern of child development, by speeding up some of the stages in it. This precociousness is probably associated with a combination of beneficial ways in which the computer can help certain learning processes along. Those beneficial aspects are interactiveness, the learner's being continually stimulated, instant self-correction, independence, creativity, and the learner's intensely active involvement" (Naymark, 1983). Similar questions are advocated in the other major areas where the NIT have been observed to correlate with surprising results.

29. Next to the impact on the time spent on learning, another strand of similarity among observations concerns the onset of certain learning processes, particularly on the apparent modifications of the age at which notions or skills can be learned. The work of Piaget or Bruner, to mention some major names, has demonstrated convincingly that cognitive development takes place in predetermined sequences, holding two main characteristics: their relative positioning is irreversible; furthermore, they mark a progressive detachment of the learner from the concrete environment towards an increased reliance on "inner" mental structures. Among the researchers who have applied such understanding to "learning by computers", the name of Seymour Papert has come to acquire a major prominence, particularly in relation to the LOGO system, in itself an application of the Piagetian model of concept formation in children during their concrete operational stage.

30. Developed at first in laboratory conditions, LOGO has acquired of late a tremendous visibility of almost mythical proportions. Its reputation is built not only on what it seems to confirm of the established models of cognitive development, but also, and perhaps more importantly, on what it seems to refute or qualify in them. LOGO has been among the first computer-based learning systems to produce additional ammunition for those who, on the basis of non-computer based research work, have long cast doubts as to some central hypothesis of established models of cognitive development. The major debate worth mentioning here is that of the alleged inability of young children to perform at formal levels of thought. Many educators have concluded from Piaget's work that children lack the conceptual structures needed to operate on abstract notions, an ability which is not supposed to develop until the mid-teens. In the recent years the evidence has multiplied on the cognitive age-marking introduced by Piaget, being influenced, and possibly changed, by factors other than cognitive, of social and cultural nature (e.g. Doise and Mugny, 1981). This newly acquired understanding has not had much influence in modifying the original belief, which has been further strengthened by findings such as those from clinical research showing correlations between cognitive stages and physiological phases of neuronal growth in children (e.g. Toepfer, 1982).

31. The LOGO-based experience has since opened the gates to a multitude of research work throwing more systematic doubts on this central hypothesis. In the words of Seymour Papert, the Turtle, the main tool of communication between the child and the computer in the LOGO learning system, makes it possible to uncover the unexpected: "My goals are education, not just understanding. So, in my own thinking I have placed a greater emphasis on two dimensions implicit but not elaborated in Piaget's own work: an interest in intellectual structures that could develop as opposed to those that actually

at present do develop in the child, and the design of learning environments that are resonant with them. The Turtle can be used to illustrate both of these interests: first, the identification of a powerful set of mathematical ideas that we do not presume to be represented, at least not in a developed form, in children; second, the creation of a transitional object, the Turtle, that can exist in the child's environment and make contact with the ideas." (S. Papert, 1980)

32. To remain in the area of mathematics learning, it is worth adding to Papert's the conclusions drawn from a recent report summarising the results of a number of researches, not necessarily computer-based. "Children", the report says, "have significant conceptual understanding of mathematics concepts at much earlier ages than had been believed previously. Early understanding of these concepts is incomplete and largely implicit, but it is clearly not totally lacking, which means that instruction should be designed to capitalise on important conceptual building blocks that children have, rather than assuming that they have no cognitive basis for developing understanding of important abstract principles." (FBPCS, 1983)

33. The evidence is suggestive and multiplying. In a number of countries systematic investigations in this area are currently being carried out. They show the enthusiasm, sometimes the euphory, generated by the promises implicit in the earlier findings. Yet a word of caution has to be said, as the investigations are not always as scientifically sound as they might appear, as sometimes the conclusions might be dictated by the expectations more than by an objective assessment of the balance between what is and what one would like it to be.

34. Surveying a number of French experiments, a recent report describes the situation in the same critical terms as could be applied to other national situations. "The material available at present is not at all rigorous, either as to conditions or still less as to results achieved, so it only warrants some initiative and rather broad comments. Every investigation concerned with younger children emphasizes the ability to look ahead that is involved in programming, because it implies being able to imagine beforehand what the outcome will be of the successive operations necessary to achieve the intended results. Children do look ahead to some extent, but their strategies (empirical, analytical...) can vary and achievements are mixed... Underlying these experiments, of which there are more and more, is a major pedagogical insight: a child's heuristic activity, brought on by having him/her work on this kind of intuitive geometry and logic, is likely to transfer to other, more academic activities... early reading (by about age four) can be taught by a technique that has already been shown to work relying on the stimulus provided by the interactiveness of the computer. The findings of research along these lines will be worth close attention...

35. For older children, the committee assessing the computer option in the lycées has made various comments on learning to program. Unguided, spontaneous programming (which children can do because a certain number of algorithms can be programmed very quickly) results in programs whose complexity reflects whatever level of capability the child has reached for reasoning in the abstra[illegible] A child who can grasp a purely sequential process will have no difficulty in writing a set of "do" and "if" instructions. One who can grasp iteration will have no difficulty in including loops... There is probably a need to check whether any attempt is or is not being made to

inculcate knowledge via computing beyong the pupils' usual level." (Naymark, 1983)

36. It is not the objective of this report to assess the scientific merits of one or the other line of research on the sequential organisation of learning. For the purpose of this report -- to clarify what might be the possible impact of the NIT on learning -- the evidence, as well as the doubts, reported above stress a central meaning of the results obtained: the great potential of the NIT for understanding learning processes.

37. Some of the observations and results discussed here, and most of those analysed subsequently in this text, indicate the double role of the NIT vis-à-vis learning processes: as modifiers of the processes and as tools for understanding them. The introduction of the NIT in the learning environment leads (although not systematically and according to modalities still largely unknown) to changed performances of the learners. The observed changes indicate some modification of the learning processes underneath and/or of their cognitive and motivational determinants. This, in itself, is conducive to better understanding of the processes.

38. But the impact of the NIT on learning goes farther. By providing the technological support for increasing the flexibility and richness of the learning environment in terms of information, exploration and discovery, and, most of all, by making data collection and analysis fast and undemanding, it qualifies as an important tool of research on the effects it produces. This double impact of the NIT on learning is an important issue to underline at this point of the analysis, as it will accompany the reader throughout this report. The contention is supported by evidence in this section and constitutes one of the conceptual pillars of the subsequent one, when analysing the impact of NIT on pedagogy and education. It constitutes also one of the central considerations of the conclusive section on priorities for the future.

THE CONTEXT OF LEARNING

39. In the quest for what makes learning possible, few would deny the important role played by contextual factors, such as the presence of a "tutor" or the interaction with the peer group, or with specific technological supports. Yet in the study of learning by the NIT, this area of enquiry has remained largely neglected.

40. The few fragments of evidence available tend to cluster around topics such as the merit of individual vs. group learning, or the personal reaction of the young to the computer. Some North American studies report favourably on the effective/emotional outcomes of "learning with computers" or speculate about "useful social effects when co-operation is supported rather than competition" (Crossley, 1983)

41. Some Scandinavian experiences from the upper grades of the compulsory school, from general secondary schools and from upper vocational institutions, show that there are pupils, although admittedly mostly boys, who are highly motivated to learn by way of the NIT and ready to use their time and energy to

find out ways to develop themselves in the new skills (Ruoppila, 1983). These observations are not paralleled by any deep understanding on the resulting cognitive and social development of the students, although, at least at face value, they seem to indicate an improved level of social interaction and a transfer of benefits to the advantage of students' school work in general. An official publication on the evaluation of the Swedish project PRINCESS (aiming at studying the feasibility and desirability of learning by computers in schools) is explicit on this point: "The various computer aids used have been found to improve the quality of teaching and learning... Project work is made easier by computer aids. It was also found that computer aids could be usefully employed in group work involving two or three students. Word processing was the only connection in which students did better working individually. Co-operation between students improved in most cases." (CLEA, 1983)

42. But even word processors do not necessarily lead to isolated learning, if only the organisation of the learning environment changes. A small-scale Canadian study, for instance, has found that "when children had access to their own private terminal there would be little interaction about their writing tasks because they would be so eager to work on their own projects." (Kane, 1983). This apparent confirmation of the Swedish findings on the use of word processors is, however, confuted by findings such as those of another Canadian study on the effects of a second monitor standing facing the pupils at the head of the class. This second monitor was found to generate intense socialisation between the users of the simple word processing facilities and their classmates. "Perhaps", the author comments, "having a limited number of terminals for word processing use would be a blessing in disguise..." (Logan, et al. 1983).

43. Other observations of Canadian classrooms confirm that "independent" learning with computers is not necessarily synonymous with "isolated" learning: "Observations in classrooms with microcomputers available for regular use indicates that the keyboard and screen become the focus of small group relationships among students who are intent on solving problems. This phenomenon is contrary to earlier predictions, based on experience with library carrels and with senior students intent on academic studies." (Crossley, 1983)

44. If the pupils and students like the computer there must be a reason. Very little is known on this subject besides anecdotal personal reports. Some interesting insight comes from sparse observations showing that whatever their determinants, the reactions could be, for instance, class-dependent. A survey of experiments in the French primary schools indicates: "original investigations into childrens' perceptions of the computer show that drawings by children from comfortably-off backgrounds are fairly stable over a full year spent using the computer, while drawings by less privileged children evolve from an anthropomorphic picture of the machine (e.g. spiderman etc.) towards a more instrumental one." (Naymark, 1983). Children's reactions can also depend on the degree of familiarity with the computers: the more familiar the child the more realistic his/her representation of the computer's possibilities (INRP, 1981).

45. Observations of older pupils in remedial education suggest that computers might have specific "motivational" virtues: "in a context of all-round failure at school, computing as an activity strongly stimulates and

motivates pupils. The positive reinforcements, the ability to check out an abstract activity immediately, the scope for creativity, the ability to reverse the traditional teaching situation by instructing the computer, all help the pupils to get out of their anti-school attitude and build up their confidence in themselves." (Naymark, 1983).

46. Similar positive reactions to the computer are reported by a Canadian teacher: "Watching many learners use courseware leads increasingly to the belief that the learner learns more and more happily, when he or she has control over his or her own objectives and methods of learning" (Godfrey and Sterling, 1982). Requested to identify the most satisfying use of microcomputers in their classes, 74 per cent of Manitoba teachers indicated: "motivation and interest of the students" (M.T.S., 1983). Other positive attitudes are reported anecdotally from Scandinavian countries where the introduction of the computer in the classroom has often generated "clear positive effects on teacher-pupil relationships, due to the enthusiastic feeling and common interest which make the interaction democratic" (Ruoppila, 1983).

47. However patchy, the above data indicate rather clearly how interactional and organisational variables are increasingly appearing as major factors in determining the kind of learning taking place via the NIT, although, again, the specific modalities of the impact are not as clear. The subsequent section discusses further the role played by the variables more specifically linked to the management of the school. What could be underlined here as a partial conclusion is the growing awareness of the contextual organisation of learning, as being an area of enquiry as important as it is uncharted. As modifiers of the social environment of learning and of its support structures, the NIT can safely be expected to influence learning. Research and experimentation work is needed to ascertain the kind of impact thus produced, the kind of changes introduced on learning, the kind of learners likely to be affected more than others and in which ways.

THE CONTENT OF LEARNING

48. Of the little information that exists on the impact of the NIT on learning processes, this is the area where most of it can be found. This polarisation of research efforts reflects the central mandate of education, namely the equipping of the young with the basic knowledge and skills to lead a socially integrated adult life.

49. Within this general context, the bulk of research generated so far has stemmed from a more specific concern: the acquisition of basic skills. Two main trends can be identified in this area: one aims at clarifying the impact of the NIT on "old" basic skills such as reading, writing and numeracy; the other aims at analysing the emergence of possible "new" basic skills, more directly linked to the cognitive demands and possibilities opened up by the new technologies. The debate on the cognitive value of computer programming skills is central to the latter trend. In both cases, strict cognitive concerns are parelleled by an equally strong emphasis on the NIT as a tool to improve the efficiency of the educational system.

Reading

50. In the realm of learning to read, the NIT could influence the process in a variety of ways: they can operate on the learning environment, on the motivation of the learners and their tutors. They can also -- and these are the issues on which most of the evidence is based -- influence the process by introducing new content materials and new technical supports, as well as by making different teaching/learning approaches possible.

51. The issue of reading skills as content-bound is an old one to which a number of analyses have been devoted. Some of them have been articulated in terms of quality and familiarity of the schools' reading materials. The contribution of the NIT to the quality issue is far from clear. Whatever the diagnosis of the merits of current instructional material, the question remains unanswered as to what beneficial effect could be expected by the NIT. A priori, there is no reason to suppose "that the pedagogical acumen of people who write computer software is going to be any greater than that of people who write paper-and-pencil workbooks" (Anderson, 1983). In that, the NIT do not introduce new terms to the debate, but re-propose under a different form, such as software development and authorship strategies, concerns already established.

52. The issue of familiarity of school reading, on the contrary, qualifies as highly relevant and specific to the possible influence of the NIT on reading. A central question to the acquisition of reading skills is whether any suitable materials of instruction can be used to teach skills of reading and writing. The developments observed in most Member countries over the last decades seem to provide a positive answer to it. In most schools the material used to teach to read have not ceased to multiply and diversify. Today's pupils learn to read from a large variety of textbooks, mimeographed sheets, games and other instructional tools. Without any doubt these developments are a plausible solution to some of the problems at the origin of recent and less recent school changes. Decentralisation, autonomy, multiculturalism, alignment with real-life concerns, have all led to increased curriculum differentiation across schools, as well as increased variety across classes.

53. The extent to which these changes are also solutions to the problem of the quality of reading skills is much less clear. A recent line of research suggests strongly that the proliferation of different materials, by exposing the learners to an increased amount of unfamiliarity, can severely offset the benefits gained from their quality (Hirsch, 1983). The quality of a text -- the model claims -- makes a difference in comprehension only when the learner is familiar with its subject matter. Familiar reading material produces the expected effects: good style is all the more helpful to comprehension when the content is difficult. Exposure to unfamiliar material, however, tends to produce reading performances that are counterintuitive. Here good style contributes little to the quality of reading.

54. Subject to confirmation by other researches, the role of content familiarity on the acquisition of reading skills could well be a crucial one in the area of the NIT. As noted before, perhaps the largest potential of the NIT is for the quantity and variety of information they give access to. To what extent this new power could turn into a Pandora's box for the acquisition of basic skills such as reading, is a question deserving careful scrutiny.

55. The issue of reading skills as support-bound is also one that qualifies for close analysis. The intuitive idea of an unavoidable specific influence of technologies such as the computer on the acquisition of reading skills begins to be substantiated by clinical research showing how, when reading from a visual display screen, the brain produces wave patterns different from those corresponding to reading from a printed text (Logan et al., 1983). Some research is also investigating the possible differential effect of learning by computer on various related subcomponents of reading skills such as word recognition (the speed of which seems to increase) and word comprehension (the level of which seems on the contrary to decrease)(Collins, 1982).

56. Finally, another area worth mentioning as to the possible impact of the NIT relates to the teaching/learning strategies whereby reading is taught in schools. Despite the considerable progress made in related fields such as in linguistics, the approach to teaching reading has undergone little change over the decades. It was, and still is, essentially phonetic. Children are taught to learn to read by matching written symbols to sounds. Over the years, and depending on the countries, letter recognition has been replaced by syllable or word recognition as a couterpart to sound. But the relationship has remained phonetic. Other approaches through grammar or meanings have remained, for good or worse, largely absent from the classrooms. To the extent that computers have no voices (in itself a temporary condition) such approaches might be replaced by others, the effects of which on the acquisition of the skill are still uncharted.

57. If the above list of issues might look like a dog's dinner to some, the impression would be essentially correct. If little is known on the impact of the NIT on the acquisition of reading skills, this is also because little is known as to the deep nature of reading, which in itself makes it hard to develop an analytical structure to discuss possible influences on it. At best, reading is only "a partially observable, partially decomposable process, best conceived as a system of interacting component processes" (Anderson, 1983) which are far from being understood. Perhaps the most important impact of the NIT could be expected precisely at this level, to make reading understood. In this context, lines of research on reading difficulties, on the diagnosis of reading strategies and errors are possibly one of the main priorities in this area.

Writing

58. That writing can be decomposed in a sequence of stages is an assumption shared by most of those who teach to write. What they would be less ready to accept is what is more important in assessing the skill level acquired: the quality of the final product or of the process producing it.

59. As for reading, the study of what makes writing possible, and at what level, has undergone several developments over the years. The shift of attention from the products to the process is the latest one brought about by empirical studies of writers' behaviour and parallel progress in the understanding of the cognitive processes underneath. While it is not within the aims and possibilities of this report to discuss at any length the problems encountered or the results achieved in this field, it is worth emphasising here one of the conclusions of an expert: "All children can learn to write... Young children are able, given support and guidance... to adapt

the powerful language learning strategies they employ in learning to speak to the process of learning to write" (Gundlach, 1983)

60. If we draw the parallel to language acquisition in this section on writing, it is less to support any school of thought claiming a link between the two than to underline the specific role that the NIT could play in learning to write. In learning to speak, the child has no other mechanical skills to master than the sensory motor control of his own organs. Writing with pencil and paper is much more taxing. The sensory motor control of arm and hand drains much of the resources of the child. How to concentrate on ideas, how to focus on structured paragraphs, how to retain the thread of a story, when so much effort is required just to draw letters and words.

61. It is in this area, the writing skills of beginners, that the NIT are already having a visible impact on learning, by way of the word processor, which eliminates most of the mechanics involved in writing. The impact on the speed at which the skill is mastered, in terms of syntactic and grammatical correctness is particularly visible with those children having difficulties via the normal practice and with the youngest among them.

62. Although much needs still to be done to understand the reasons why the process is facilitated by the word processor, why writing as problem solving is improved, it is interesting to note the wealth of anecdotal evidence from the users themselves. In primary as well as secondary education, pupils report why word processors are better. With them, they say, there is less concern about making mistakes as corrections are easy (and can be made away from teachers' eyes). The text looks better, and this makes it easier to fix errors and ideas. Typing doesn't hurt the hand like writing does. (e.g. Naymark, 1983, Collins 1982).

63. Such physical and psychological benefits are claimed by older writers as well. As a recent report puts it: "The psychological inhibitions of writing and rewriting letters or essays... almost disappear. Even spelling corrections become a form of 'debugging' rather than fault finding with penalties. There is enough empirical evidence in classrooms as well as in the offices of business and industry to illustrate the 'freeing-up' of the thought processes that takes place as a result of the relative freedom from the mechanics of writing and/or typing." (Crossley, 1983)

64. Having been freed from its dullest demands, writing can be learned in different ways; for instance, by experimenting different strategies for composing essays. This is the objective of newly produced software such as the Essay Outliner, produced by Canadian teachers, whereby the students can either outline a sequence of topics, then expand them to create the essay or, alternatively, adopt a wholistic approach from which to extract the elements of the structure or outline. The production of such software stresses the importance of providing writing alternatives especially in the primary and early secondary years of school when the creativity of all students should be fostered, while skills are taught.

65. But dinners, even dogs' dinners, do not usually come for free. As with reading, not much systematic knowledge exists as to the cognitive processes involved in writing. Although not many "warning signs" have shown up as yet, the risk that the NIT provoke side effects less positive than those reported above remains. Here, as for reading, as progresses are made in research, the

awareness grows on the complexity of skills subsumed under the generic label of "writing", hence of the multiplication of the possible side effects inducible by the technologies. The sharp differences ascertained between novices and expert writers are only one of the new avenues of investigations in this area. The difference in the skills underlying the writing of short, as opposed to long, texts is another.

66. As with reading, the contribution of the NIT to writing can be expected at different levels. They can facilitate the acquisition of the skills as we know them. By the same token they can have other unforeseen effects on what is still unknown. Perhaps, even more importantly, they can be used to understand the processes themselves, by reconstructing the strategies developed by the writers to write, to correct, to revise.

Numeracy

67. A recent report from the US (Davis, 1983) describes the situation in the field of mathematics learning, which could be easily generalised to other countries:

-- A very large number of students can learn considerably more mathematics than they typically do at present;

-- The discrepancy is particularly pronounced in the case of mathematically gifted students;

-- Many students are in fact learning far less than they are believed to be learning.

68. In order to tentatively assess the impact of the NIT in this area, it is useful to analyse some of the reasons believed to be at the origin of the outcomes observed. Some trace the roots of the problems back to the widely-based (and incorrect) conceptualisation of learning mathematics at the origin of the 1950s and 1960s movements to improve learning of scientific subjects, whereby "knowledge" was measured by the selecting of correct responses to a relatively small collection of questions (Davis, 1983). Currently, the new wave of research in this area is emphasising what had been pointed out by pioneers such as Jean Piaget, namely that it is a mistake to focus only on "right" and "wrong" answers, and ignore the reasons why people select different answers. In other words, the new generation of research on numeracy, similarly to that in reading and writing, has shifted the emphasis from the products back to the process.

69. Another reason often advocated to explain the less-than-satisfactory results in mathematics learning is, even more basically, that the approaches used so far have not aimed at developing teaching/learning strategies specific to children. Speaking of modern mathematics, S. Papert says explicitly that "it did not come from a process of invention of children's mathematics but from a process of trivialization of mathematician's mathematics." (Papert, 1980).

70. The combination of the two trends of thought might find in the NIT a particularly useful tool to progress in understanding as well as in developing new approaches to the learning of mathematics. The computer has already been

given an important place in the learning of mathematics concepts, for instance by way of the LOGO system. For older children, pocket calculators are already performing a useful role in animating the debate, if not in providing answers to it. In the area of remedial education, computers have been used to analyse error generations. This has provided important information on thought processes which has led in turn to improved learning.

71. In this area, the field where most of the results have been gathered is also where there is less certainty as to the beneficial effects of the NIT on learning: the learning of mathematics by drill-and-practice. A typical result would indicate that drill-and-practice has a positive effect on computational mathematics, but that increases in conceptual understanding of mathematics are sometimes greater, sometimes less, than for control groups. (Ragosta et al., 1981)

72. In this area, as in others, the potential of the NIT is as great as the need to understand the variety of observed phenomena and the possible development of new approaches to learning. In particular it is important to analyse what works and what does not work, in which learning environments, with which learners and which technologies. In this context, in mathematics as well as in reading or writing, given the accumulation of uncertainty as to the processes underneath, generating the right questions is possibly more important than finding answers to meet what look like the most urgent needs.

The evolution of basic skills

73. A recent report says cogently: " A continuing dilemma for curriculum decision makers in all school systems is created by the concept of basic skills. There is adherence by many people to the idea that reading, writing and arithmetic are the "basics" of education. Conservative or traditionalist educators tend to combine this notion with an emphasis on drill and practice, and uniform standards. On the other hand, education should prepare students for contemporary society and/or the future, and should do so for as many of the students as possible. The question of what skills are to be offered by the school system and the best processes of teaching and learning to achieve not only skills but those higher order goals expected of education are issues that tax the judgment of educators and politicians." (Crossley, 1983)

74. Another author brings the issue of basic skills down to its own basic level, its link with literacy: "Literacy is not just a formal skill; it is also a political decision. The decision to want a literate society is a value-laden one that carries costs as well as advantages." (Hirsch, 1983)

75. The above quotations highlight some of the main issues in the debate on basic skills and on literacy. One is that the definition of basic skills is, to an extent, one of convenience, dictated more by what are supposed to be the needs of the time for integrated social life than by what are supposed to be the needs of single individual lives. The second is the translation of convenience into uniformity, one further step away from individual specificities, perhaps one towards social equity. The third is the notion that the promotion of literacy, whatever its definition, carries costs as well as advantages, for individuals as well as society.

76. The new information technologies and the knowledge and skills related

to them have come to occupy a place of prominence in the revived debate on basic skills and on literacy, where they are often seen as fullfilling a possible double role. They are counted upon to insure the acquisition of "established" basic skills and identified as indicators of new ones to include in the making of the new literacy. A first corollary concern in the debate relates to their possible role in making some basic skills obsolete. A second one bears on their possible impact on the gap between the satisfaction of societal needs and the respect of individual differences. A last one, implicit in many discussions, looks upon the NIT as the "miracle" remedy to make education succeed where old ways have failed.

77. The analysis developed before reveals that the NIT have the potential to play all the roles expected of them, within reasonable limits. The fact that not much is known as to their specific effects on learning is only a temporary drawback. Given enough investments in research and experimentation work, the understanding will be reached as to the details of their functions at all levels.

78. The evidence produced so far indicates that the NIT can be of assistance in the teaching/learning of the "old" basic skills. Reading, writing and numeracy can be facilitated by the use of the computers, although it is becoming clear that the observed benefits might come at a price. Speed of reading might be increased at the expense of text comprehension. Multiformity of reading materials can be achieved more easily, possibly at the expense of literacy levels. Literacy in the 3Rs could be acquired earlier in life at prices still unknown in terms of individual development. Writing can be facilitated at the expense of sub-skills such as grammatical or spelling literacy. It could even be made obsolete by the increased availability of visual (graphic) forms of communication. Numeracy can be achieved with less effort and in less time, but possibly at the expense of the specific thought processes developed from some number manipulations.

79. But the impact of the NIT goes well beyond their possible influence on basic skills. They can create the need to acquire new ones. Some likely candidates are emerging more forcefully than others. They are linked to the largest potential of the NIT, access to information. Put plainly, once information and data can be retrieved at will, memory and recall skills, central to established teaching/learning methodologies, will become peripheral to learning processes. Instead, other skills will acquire importance. The ability to deal effectively with novelty might become as important as the ability to deal effectively with repetition. Working with computers often develops a generalised attitude of enquiry, of "trying out", rather than relying unquestionably on the knowledge pre-packaged by the teacher. The need to develop personal learning strategies might become a must to orientate oneself amidst the options available. The list will only get longer in time.

80. As for "old" skills, the new ones will not necessarily come for free. The focus on individual learning might be detrimental to those who cope badly with learning without a human coach. The multiplication of options and possibilities might handicap further those who, in the absence of firm guidance, tend to "get lost" or to resort to earlier learning attitudes that are not necessarily beneficial. In short, the strong learner might grow stronger, the weak weaker. The consequences for uniformity, individual differences and, in the end, social equity might be substantial. Unless...

81. As in the best stories a new character could perhaps be brought on stage who, as the "deus ex machina" of Greek tragedies, will, by means of special powers, solve the problems possibly created by the NIT, or like the medieval philosophers' stone will turn the vile metal of basic skills into golden intelligence, thus providing all humans with power of their own to counter the possible harmful effects of the technologies. Learning to program a computer, most seem to believe, will do more for people than making them acquire a basic skill: it will expand their intelligence, it will develop their brain, it will give them a thorough, sharp mind. Humans will then grow all the wiser to avoid "technological" prejudices.

The "other virtues" of computer programming

82. Although caricatured, the issues raised in the previous paragraphs are very real in their substance. A number of policy decisions as to the introduction of the NIT in education rest on the assumption, at times more explicit than at others, of the "other virtues" of computer programming. Many heated debates on the curricular value of computer programming develop around the belief of some, and the disbelief of others, in the therapeutic value of this skill for the pupils and for the institution.

83. As a recent report puts it: "There was a time when it was generally believed that in learning how to do geometry, one learned the generally useful skill of thinking deductively and rigorously. Similarly it was believed that in learning Latin one disciplined one's mind and made it thereby more conducive to learning in general. More recently, it has been suggested that the teaching of computer programming might be an effective vehicle for the teaching of generally useful cognitive skills. There is very little evidence that the expectations for geometry and Latin were warranted. What reasons are there to expect that the learning of programming would produce more substantive results?" (Nickerson, 1982)

84. The debate around computer programming rests on a scant data basis indeed. Little is known as to the nature of the skill or its cognitive benefits and even less on the "transfer" value of whatever is specifically acquired. Without doubt this is an area where investigations, thus adequate investments, are needed especially urgently. Among the many aspects of the problem to analyse, important ones, with immediate relevance to education, would be:

-- The definition of the concept of computer programming;

-- The cognitive prerequisites to its learning;

-- Its cognitive consequences, including the issue of transfer.

85. As with many other skills when examined at close range, computer programming ceases to look like the convenient unitary label it is often taken to be and reveals its real nature, which is very complex. Defined as a body of knowledge or a skill to master, computer programming can entail different cognitive prerequisites and have different cognitive consequences depending on a number of factors. Among them, the programming language is as influencial on learning as is the specific kind of software it is meant to produce. The hardware configuration, the learning environment, are all additional, and

important, factors to consider when establishing learning approaches in this area, or when assessing the learning taking place.

86. One way to analyse the cognitive prerequisites of computer programming is to study possible correlations with other and better known cognitive abilities and factors. After having surveyed the scant literature in this area, a recent report draws a tentative diagnosis: a number of cognitive skills have been identified as possible correlates to programming skills but only very few have been the object of investigation so far (Pea and Kurland, 1984). The list includes items such as memory capacity, analogical reasoning (possibly a crucial skill for transfer), conditional reasoning, procedural thinking, temporal reasoning. Among the few investigated, mathematical abilities top the list, followed by IQ correlational studies. In both cases the typical correlation found is either modest or unclear. In the words of the reviewers, "to our knowledge there is no evidence that any relationship exists between general maths ability and computer programming skill once general ability [intelligence] has been factored out. Nonetheless, general maths ability per se cannot yet be ruled out as a possible prerequsite to the successful mastery of computer programming skills".

87. The correlation with IQ has been explored only indirectly, in relation to the ranking or scores in programming courses rather than with programming skills per se. In this context, adults' IQs have been observed to correlate, albeit modestly, with such indirect measurements. It is worth noting that no relationship has been established between the performance of adults on such scores and their subsequent performance in computer programming in the work place (Pea and Kurland, 1984).

88. Besides the difficulties inherent to the nature of the skills to analyse, still poorly understood, or the influence of outside factors, still largely uncharted, the study of the cognitive correlates of programming skills is beleagued by a number of other problems. Among the factors qualifying as major determinants of learning one could easily count the age of the learners and their degree of familiarity with the computers, prior to the tests.

89. Cognitive abilities by age are obviously a central issue in the debate on how and when programming should be taught in schools. A recent survey of U.S. evidence proposes broad tentative conclusions in this area (Becker, 1982). Children in grades K to 4, the report says, can learn rudimentary programming operations, particulary in special languages like LOGO, in which almost all operations are built from a few primitive operations. At about age 11 or 12, the report continues, a general improvement is observed in planning general structures and devising comprehensive computer tools, but only after a good deal of effort and guidance on the part of the instructors. Students in grades 6 to 8 seem, on average, sufficiently mature to understand the abstractions involved in programming. Older students, on the other hand, seem to separate into two groups: a small proportion who are personally interested in programming activities and a larger proportion who view the computer as just another subject in the curriculum.

90. Another report, surveying French computer-related experiments in schools, suggests that great caution should be used in generalising results by age, as the differences within same-age groups could be as large as the differences found between groups (Naymark, 1983). An in-depth analysis of a

LOGO experiment in primary education has revealed that only two thirds of the children have no difficulties in mastering the concepts and the relative programming activities. The remaining third experience difficulties in learning the same concepts and usually abandon programming above a given threshold of complexity. On the other hand spectacular results, well above their usual school performances, have been obtained with no more than 2 or 3 pupils per class, notoriously shy and withdrawn.

91. Within a school population of more modest social origin, an experiment of computer-based remedial education, has also led to differentiated results. The computer was found to be a formidable pedagogical tool to bring about improvements in the social and psychological make-up of the pupils. Its impact on their school performance was however uneven. Good, even spectacular results, have been obtained with no more than half of the pupils. With the others, improvements have been obtained only on some of their assessed deficiencies, such as in learning concepts of geometry, in overcoming problems of lateralisation, or in holding prolonged concentration on a task (Naymark, 1983).

92. In general the results reported in the literature on the learning of computer programming show a variety of outcomes ranging from enthusiastic, to cautious to negative ones. Some of the differences in the results have been claimed to derive from the different programming language used in the studies. With older learners, some say, the language chosen does not make a big difference in the observed outcomes. More important in these cases seem to be issues such as the resources available in the programming environment, how programming instruction occurs and the amount of program writing and debugging students engage in. (Pea and Kurland, 1983)

93. For children, on the other hand, the computer language could make the difference between learning and not learning. Not much disagreement exists on children being more successful at learning LOGO than BASIC, for instance. Yet the issue of language per se, if taken too exclusively, could prove to be misleading. Perhaps, some authors say, it is not the language that makes the difference but rather its "programming environment". In this context, many of the alleged advantages of LOGO over BASIC as a language for children could lie in the sophistication of LOGO's programming environment (Pea and Kurland, 1983). For example, LOGO has a much more sophisticated editor, more detailed error messages, better debugging procedures and greater finesse in creating and manipulating files.

94. Yet other studies identify a main factor in determining performances in computer programming in the prior familarity with computers. It would be a truism to say that differential access to home-based computers could explain some of the better performances observed in schools. In addition to such common-sense observations, harder data are being gathered which tend to confirm the above hypothesis.

95. Studies on adult learning have shown in Scandinavian countries how, when learners have used computers in their daily work for some time, the skill of programming them is acquired at a higher level and in a shorter time (Ruoppila, 1983). Surveying a body of research work on novices vs expert adult learners, a recent report confirms the existence of large differences between the performance of the two groups (Pea and Kurland, 1983). Among the most relevant results one could mention that the acquisition high-level

computer programming skills seems to be characterised by a giant assembly of highly specific, low-level knowledge fragments.

96. Additionally, large differences have been found in the way experts, intermediate and beginner programmers develop mnemonic strategies: for instance, experts cluster the keyword commands according to meaning whereas novices use a variety of surface ordinary language associations. Finally, a common result concerns debugging techniques: experts read programs for flow of control (execution), novices use line-by-line (as text) techniques. It is interesting to note that similar "strategic" differences phrased in terms of deep meaning or superficial connotations of concepts and processes are emerging from studies of novices and experts in the field of physics (Nickerson, 1982).

97. Although far from exhaustive, the data analysed in the previous paragraphs are convincing enough: the hopes on the cognitive benefits to be gained from computer programming skills might be, to an extent, unrealistic. Diversity seems to be the key word in this area. The skills rest on an aggregate of subskills, the study of which has only just started. The cognitive prerequisites for acquiring them vary accordingly. Not all learners have them. The cognitive consequences also vary, depending on a number of factors, suspected rather than charted. Yet, a number of people in various situations have been observed to perform surprisingly well on computer programming tasks, suggesting important gains at the cognitive level. Clearly, computer programming has a cognitive value. It remains to be seen in which conditions,with what people and to what extent the expectations could be satisfied.

98. Given enough investment, in terms of time and research, it might well appear that computer programming can facilitate, without being necessary nor sufficient, the development of particular cognitive abilities. Planning, precision, generation and testing of hypotheses, formulation of problem-solving approaches, are all cognitive abilities involved in computer programming, at different degrees. Probably the learning of computer programming will prove to be of benefit to these more general cognitive domains. In the affirmative, the debate on the desirability to teach computer programming to all pupils, and, consequently, on the curricular status it should be given, could well end by endorsing a weak rather than a strong hypothesis as to its cognitive power. But even then the question will remain of whether the same cognitive effects could not be achieved without the computers and with other teaching/learning methodologies.

99. The question of the hidden costs and cost-effectiveness of the NIT in learning is part and parcel of the debate on the cognitive aspects of learning basic skills, the old as well as the possible new ones. The question is also central to the general debate on the role and impact of the NIT on learning. This section has highlighted what that can possibly be, through a series of arguments worth bringing to light in these conclusive paragraphs.

100. The evidence available tends to support the general contention that the NIT have an impact on learning processes. The same evidence, however, does not provide clear grounds as to what processes are affected most, in which learning situations, with what people. Such a situation of uncertainty as to the specific impact of the NIT seems to be determined more by the current

understanding on learning (which is inadequate) than by an insufficient understanding of the technologies.

101. Trends are emerging, however, which indicate how the situation might evolve in not too distant a future, under the combined effect of progress in the cognitive sciences, where research investments are growing, and enlarged introduction of the NIT as support tools of experimental paradigms. The foreseeable picture of the learning sciences is therefore one where the NIT can very well play a central role in fostering understanding, although, most probably, at a price.

102. The evidence discussed before shows the manifest value of the NIT as a working partner for the researcher. The same evidence, however, warns that the partner can grow rather demanding. Its hidden power rests on the ability, unique to the NIT, to perform simultaneously the double role of "revealers" and "analysers" of learning processes. The NIT will help unveiling the underlying dynamics of cognitive factors. They have also the power to analyse the processes quickly, effectively and at reduced costs. This double ability makes the NIT extremely acctractive for research on a cost/effectivness basis. Their appeal might however conceal their power to introduce important biases in the understanding gained through them on learning.

103. When using the NIT as "revealers" of learning processes, it will be inevitable to introduce a selection on the research targets. The processes most often observed will be those which are observable via the new information technologies. Quickly, these will also become better understood among the possible array of processes on the research agendas. The risk of losing the others through the familiar chain of neglect, oblivion and, finally, denial is not unsubstantial. The next section, on pedagogy and education, shows how the NIT can be equally powerful in teaching/learning situations by transfering to these other levels their unique ability to perform the double role of support for the processes and means for their analysis as well as the risks this ability entails.

Section II

EDUCATIONAL STRATEGIES

"The view that students learn what they are taught is definitely too simple to be a useful guide for design of instructional material and teaching." (FBPCS, 1983)

"Heresies perform an essential function -- they keep people's minds on the alert." (Reeves, 1981)

104. The strength of any chain cannnot exceed the strength of its weakest link. At its outset, this section's contribution to the understanding of the possible relationship between NIT-based and school-based learning identifies itself as one of many possibilities and few certainties. In that respect, this section reflects the status of the current understanding on the impact of the NIT on learning processes, which, as analysed previously, is itself one of exploration and enquiry more than one of certitudes and confirmations.

105. Within such a framework of caution, this section develops further the analysis, in subsequent steps. It starts with the main conclusions from the previous section on the impact of the NIT on learning processes and discusses the implications for pedagogical approaches. Next, it attempts to apply pedagogical methodologies to educational practices, by considering the ways in which the institutional system could or would accommodate the resulting changes. In particular, this section highlights the implications of possible changes in formal education with respect to specific concerns such as on equality.

PEDAGOGICAL APPROACHES

106. The current link between pedagogy and the psychology of learning is no stronger than usual. Progress in the latter is having only a partial effect on the development of the former, and this with considerable delays. In that much, the tradition is being respected. Pedagogy and the cognitive sciences have followed rather separate paths in the past, with occasional bridges arising between them, when some major theoretical understanding in the latter has been transferred and adapted to the former.

107. The model of intelligence as being made up of a general factor

accompanied by a host of specific ones has been instrumental in the development of quantitative approaches to cognition as well as to pedagogy. The widespread introduction of tests to assess educational performances has been one of the most visible forms whereby such theoretical models of cognition have been used in institutional practices. Understanding of the strong influence of the environment on learning, together with the findings on the importance of early learning have accompanied the development of "active" and "participatory" pedagogical models targetted at the younger children. Models of the development of cognitive abilities as a mechanical response to stimuli (behaviourism) have found widespread applications, at least in some countries, as drill-and-practice approaches to learning. More wholistic models of cognitive development such as that developed by Jean Piaget have had a much harder time to penetrate, either pedagogy or education.

108. The more recent generation of research on learning processes has introduced some changes in the picture of what is important in learning and how it could be supported. A main change discussed in the previous section is the shift of the research target away from the learning products and back to the processes underneath. The current emphasis of research on cognition is on the concept of learning as personal discovery, problem solving and information processing activities, rather than acquistion of specific skills or "chunks" of knowledge. Within this context, another important series of results has reinforced the assumption on the importance of early learning habits for later performance.

109. But perhaps the most important common implication of the most recent findings is the hypothesis that learning could be a much more complex process than previously thought. More than the result of cumulative growth, learning abilities seem to be a question of modification, diversification and differentiation. The most recent evidence seems to indicate that, far from developing along some kind of linear algorithm, learning develops rather like a branching tree of increased complexity, with each part retaining a useful function for specific tasks.

110. The most immediate translation of these research trends into pedagogical approaches is in terms of a pedagogy centred on the learner (individualised or autonomous learning) constructed on a diagnosis of his/her previous learning habits and adapted to the ongoing learning processes via a continuous diagnosis of the learning performances. In particular, and in line with the cognitive science, the new generation of pedagogical approaches would reflect the move away from broad general theories, thus from unitarian models of learning, and the development of a variety of specific approaches, adapted to specific learning and specific learners. A first observation on these objectives is that they are certainly ambitious for pedagogy. A second is that they have always been.

111. For a long time, pedagogues around the world have been developing approaches to education aiming at rather similar objectives. Their recommendations did not rest on the understanding of learning processes, then unavailable, but they were firm about the pedagogical merit of individual attention, interactivity, interest and motivation, flexibility, personal exploration and discovery. The so-called "Socratic approach", currently adopted in computerised lessonware, is at least as ancient as Socrates' maieutics. Similar approaches have been at the basis of all the major pedagogical developments of this century. Much the same principles guided the

Italian M. Montessori at the turn of the century, the Swiss E. Claperède in the 20s, the Frenchman C. Freinet between the two World Wars and the Americans J. Dewey and B. Bloom in the 30s and 50s. In general, it would be hard to find in the last few decades, any example of educational innovation which would not be inspired by one or the other of these historical founders of modern pedagogy.

112. Why, then, this revived interest in methods that have been tried successfully for a long time already? Why this tone of "newness" on pedagogical approaches which are in fact, rather old? The answer is because of the progress in cognitive sciences and because of the power of the new information technologies. The research findings from the cognitive sciences give "hard", "scientific" grounds on "soft", although highly respected, pedagogical principles. The technologies offer the instrumental opportunity to translate the specifics of the learning processes into pedagogical practices in line with established pedagogical principles. More than that -- and this is what again is unique to the NIT -- they assure at virtually no extra cost the possibility of performing the kind of continuous evaluation which is central to known pedagogical models and confirmed by research results. It is the double role of "revealers" and "analysers" that makes the NIT potentially powerful in the area of the learning sciences. It is their double role of "translators" and "evaluators" that makes them equally powerful in pedagogy.

The NIT as "translators"

113. A number of taxonomies of computer software and courseware are based on the pedagogical approaches implicitly or explicitly built-in. Although varying in their categorial definitions, the proposed classifications are developed around the same indicator: the amount of control and independence of the learner vis-a-vis the computer. The categories usually range from the best known examples of Computer Assisted Instruction (CAI), essentialy drill-and-practice programmes, to the most recent and sophisticated programmes, where both the learner and the computer can play an active role. It has to be stressed at the outset, that the distribution of the programmes produced so far across the various categories is highly uneven. The more sophisticated the pedagogical approach taken, the smaller is the number of programmes available on the market. In that, the understanding gained in cognitive science is showing itself only slowly in computer-based pedagogy.

114. The best known examples of CAI, the computer-controlled CAI, is based on a behaviouristic approach to learning. Typically, the programme presents a frame containing a portion of the lesson material to be learned, asks a question and evaluates the student responses. Selects the next lesson frame based on that response and, optionally, keeps a running cumulative score. In the words of one author, "this is the 'hospital' model of education, in which the student is regarded as a patient to be treated, or 'programmed', by the computer. 'Individualisation' in this case means only that one student may receive a different sequence of prestored frames than another. The programme does not build a model of the student's knowledge and conceptual gaps and/or does not diagnoses his/her difficulties along the way. Computer-controlled CAI applications are useful for teaching the acquisition of facts and for helping students memorise and consolidate factual knowledge. The two major varieties of such pedagogical uses of computers are drill-and-practice and

tutorial programs. Most of the software and lessonware produced so far belongs to this category" (Feuerzeig, 1981). Another example of computer-controlled approaches to learning are some pedagogical games such as word games aiming at developing language skills.

115. At the other end of the spectrum one finds what can be called the student-controlled CAI. Here learning is viewed as an active process of investigation. The program exercises no control over the learning situation. The computer simply responds within the limitations of the program's repertoire to the student's commands. There is no prescription of what experiments the students should perform nor do the programs coach the student in any way. Software of this kind are rarer. Examples exist in topical learning areas such as mathematics, physics or statistics (Feuerzeig, 1981).

116. The so-called "expert programs", created in topical areas can belong to either one of the above categories. They have been mostly developed in medicine and applied sciences. A similar classification is that of "simulation programs", developed mostly for teaching physics, chemistry and biology. They use graphics to simulate experimental conditions. Another topical kind of program is that developed to teach foreign languages (Crossley, 1983), using computer operated slide projectors and tape recorders, where graphics can be associated with sound patterns.

117. In between the above categories, there are the so called mixed-initiatives systems, the closest to a Socratic approach to learning. Student and computer engage in a dialogue. The student can ask questions to the computer and the computer can respond as well as ask its own questions in turn. Usually the student works on a complex problem-solving task. The problem can have multiple solutions or no solution. The emphasis is on learning problem-solving procedures and strategies rather than on finding "the answer". Examples are developing proofs in logic or geometry, analysing unknown chemical substances, or finding faults in electronic circuits. (Feuerzeig, 1981). Other programmes that could be classified as mixed-initiative ones are those developed for computerized homework, where in association with classroom activities, the computer can provide clues to overcome difficulties or revert to easier problems. Candidates for this category are also the programmes that allow students to create their own computerised lessons. This, an author informs us, seems to be one type of programme most enjoyed by the students (Crossley, 1983).

118. The systems developed towards specific developmental objectives form a category of their own in the field, even though, strictly speaking, they could be classified as student-controlled ones. Systems such as LOGO are based on a genetic approach to pedagogy, stemming from the recognition of the role played by spontaneous learning (learning without teaching) in the cognitive development of the child.

The NIT as "evaluators"

119. The information discussed in the previous paragraphs indicates the extent to which cognitive models of learning are being translated in computer-based pedagogical approaches. Some additional information exists on the ways in which the NIT have been put to use to evaluate the pedagogical process. Programs have been developed to analyse specifically the error

patterns of the learners (e.g. BUGGY). Others monitor the response pattern by the students and provide feedback on acceptable alternative solutions to techers who can then modify the classwork accordingly (e.g. ESOPE). Yet others compare students' performances with models of experts' performances and establish a diagnosis of the "missing skills" (e.g. WEST). The list of strategies for dynamic evaluation can only grow longer in time.

120. Few would dispute the potential of the NIT to establish diagnosis on learning, to evaluate performance and keep track of students' progress on an ongoing basis, over a period of time, without disrupting the learning itself, as tests, or teachers, usually do. At least for the most sophisticated types of programmes, pedagogical quality is insured by respecting a number of criteria including interactivity, recognition of errors and diagnosis of conceptual difficulties in the student, modulation of the learning session according to the competence and motivation of the learner, generation of dynamic feed-back, flexibility of pathways towards solutions.

121. Much the same virtues are advocated for computer-based learning by those who have used it. One of the most comprehensive sources of information on the views of the clients is a recent report by the French "Institut National de Recherche Pedagogique" reviewing a ten-year experiment on computer-based classroom learning (INRP,1981). Asked to indicate the most important characteristics of computer-based learning, the students agreed on a number of issues. The computer computes fast, they said. It gives immediate feed-back (used by most students for immediate self-correction, a type of self imposed drill-and-practice). The computer forces the learner to think and clarify the approach to subject matters. "With the computer, it is the pupil who works, whereas in the classroom it is often the teacher". The possibility of individual tutoring is particularly appreciated: "There are 35 of us in the class, so the teacher can't tell each of us individually what to do. With the computer, it's as though there were one teacher for two pupils". Personal autonomy with respect to the teacher is also appreciated: "We don't feel we have the teacher on our backs. The teacher is more in the background...", "the teacher isn't always on top of us correcting our mistakes". "We can give a wrong answer without looking stupid, which we can't in an ordinary lesson". "We're allowed to make a mistake". "The computer asks us a question and we answer, and if we get it wrong we can try something else". "The teacher is only there in case he's needed". Personal autonomy with respect to time is another point mentioned: "we have more time to think and we can slow down or go faster depending on what we can manage".

122. So far the analysis is promising: the NIT can play a role in fostering understanding of the learning processes and in applying it in practices of pedagogical quality. The analysis is equally clear on the risks involved, on the "perverse" or just the "unexpected" effects possible on the way. Cognitive scientists and pedagogues are faced with a highly appealing and difficult task: how to bend the NIT to support their work, how to maximise the advantages while keeping the disadvantages under control. The balance is difficult to strike, the challenge worth considering.

123. At this point in the report, the ground is ready to ask the next set of questions: what impact could the NIT have on learning as it unfolds in the institution of education? How to transfer the cautiously optimistic expectations from the experimental conditions to which they apply, to the much broader area of ordinary schools, without weakening the partition between the

useful and the useless, the promising and the damaging, the possible and the unrealistic? If their promises are so enticing to the pedagogue, if their use seems to be so appealing to their (so far sparse) young clients, how can the educator and the whole school population also be made to benefit? How can the pedagogical objectives of the educational system be attuned to the NIT? And finally, what would be the impact of the large-scale introduction of the NIT in education on the other objectives and functions of the system?

FROM EXPERIMENTAL TO MASS EDUCATION

124. The stakes are clear. The NIT qualify as a vehicle to integrate in mass education some of the pedagogical principles familiar to innovators, reinforced by the "hard" cognitive foundation currently being built. The resulting pedagogical methodology -- it has to be stressed once again -- is not exclusive to the technologies. Given time, resources and specialised manpower some, if not most, of what is currently developed could be carried out without the new technologies, by people working with ordinary educational tools. This has happened in the past and could happen again, but -- and this is the crucial point -- not everywhere in education. Modern pedagogy has entered the classroom mostly in isolated innovative schools, where there is a long-standing tradition of children learning at their own pace, according to their own abilities and interests, within a flexible curriculum, under the guidance of personal tutors.

125. Usually, the circumstances of such innovative education have been quite exceptional: outstanding teachers, adequate resources, a supportive community. These conditions are not easily reunited in the educational system, where the absence of them is more the rule -- a formidable barrier to any large-scale introduction of the pedagogy underneath. This is the point in the relationship between pedagogy and mass education where the NIT have the largest impact to make. Their role is not so much to make a new pedagogy available to all pupils -- the pedagogy proposed is not entirely new. Their potential is to offer a service of quality, based on sound pedagogical principles, in situations that are not exceptional to the system, at a cost which could be afforded by all.

126. The important question now is to ascertain whether the historical obstacles preventing the large-scale introduction of modern pedagogy could be removed to make room for the new technologies, whether the educational system can operate the shift from a pedagogy of convenience to a pedagogy of efficiency.

127. When considering the ways in which learning is organised in the typical classroom of OECD Member countries, not much is found suggesting that it will be easy, or painless, to make room for the pedagogy carried by the NIT. Current practices do not allow much autonomy to the learner, nor much interactivity or personal exploration and discovery. A large-scale survey of US schools has revealed classroom situations that are common to other countries (Goodlad, 1983). "Teachers varied in the quality of their lecturing, for example, but 'teacher talk' was by far the dominant classroom activity. Teachers rarely encouraged student-to-student dialogue or provided opportunities for students to work collaboratively in small groups or to plan,

set goals, determine alternative ways of achieving these goals" "the emphasis was on recall, not on problem solving or enquiry". "We received an overwhelming impression of students' passivity. Furthermore they apparently rather enjoyed the dominant activity of listening, which demands so little of them".

128. Besides the teacher-dominated instruction, very little time if left to the class to engage in other activities, either individually or in small groups. "At both elementary and secondary levels, approximately 75 per cent of class time is instructional, while most of the remaning time is spent on routine work such as preparation for instruction, role-taking and cleanup". "Nearly 70 per cent of total class time involves verbal interaction or 'talk'". "Approximately half of the verbal interaction time is devoted to teacher talk" "Less than a fifth of the time involves student talk" "Teachers, therefore 'out-talk' students by a ratio of nearly three to one". "Barely 5 per cent of instructional time is spent on direct questioning (of a student by a teacher)". "Less than 1 per cent of that time is devoted to open questions which call for more complex cognitive or affective responses". "Nearly 67 per cent of the elementary students and 75 per cent of the secondary students work as a total class. Less than 5 per cent are found working individually and less than 10 per cent are found working in small configurations".

129. The conclusions of the authors are paradoxical: "To the extent that talking requires the organisation of thought and can be an important avenue to learning, teachers were doing most of the learning".

130. When considering the ways in which the NIT are penetrating the schools, the evidence mounts on the pessimistic forecast being essentially correct, at least for the time being. A number of obstacles appear more clearly than others. The teachers' "territorial imperatives" set powerful boundaries to the realisation of the potential of the NIT as do their own level of competences. Usually, teachers are careful to teach only their grade level and not to transgress on the next grade level (Burnett et al., 1983). They have also been observed to restrict students' learning to their own level of familiarity with the new technology-based learning systems (Crossely, 1983, Naymark, 1983).

131. Variables such as the organisation of the classroom have also been found to be crucial to success. The software available does not usually fit in with classroom work. Most products developed for classroom uses of micros allow profitable use by only one child at a time. For teachers to use effectively a device which is primarily geared for a single user when they have one machine per 30 children demands, at the minimum, a major planning effort (Becker, 1982). In the end, the technologies are forced to fit in with classroom practice rather than the reverse. Most of the software available is neither individualised nor adaptive. An entire class works on the same material at any given time and is expected to proceed through the course at the same rate (Feurzeig, 1981).

132. Should the situation evolve without major qualitative changes, the schools of the future would resemble those pictured paradoxically by S. Papert, who feared that the system would just absorb the change, by using "new technologies to reinforce educational methods whose very existence is a reflection of the limitations of the precomputer period" (Papert, 1980). A

French author echoes similar concerns, and emphasizes the conceptual and organisational difficulties inherent in the "quantum leap" forced on schools by the new information technologies "The main obstacle... is institutional resistance on the part of the school to any organisational change tending to displace the teacher's lecturing as the source of knowledge in favour of learning based on manipulating and experimenting. This is not just an ideological barrier, as all too often stated, because that fortress has already been well and truly breached. The difficulty is that no-one is quite sure how to approach it, and there are very few people one can turn to for guidance. It is not just habits that have to be changed, but the whole organisation of work, time and premises that has to be rethought." (F. Robert, 1983)

133. On a longer-term perspective, the forecast could however be less pessimistic. In countries where the NIT have entered ordinary classrooms more extensively than elsewhere, where teachers and pupils have had more time and opportunities to use, essentially, the microcomputer, trends are emerging indicating that, in the long run, desirable qualitative changes could, perhaps, take place.

134. The Centre for Social Organisation of Schools of the John Hopkins University, is analysing the use of microcomputers in ordinary United States schools, at the primary and secondary level (CSOS, 1983 and 1984). A first important result of the analysis is that the introduction of the microcomputers in schools generates a dynamic, rather than a static, configuration. As time goes on and as more equipment is available and more teachers are involved, the use of the microcomputer evolves. Such evolution -- and this is the second most important result -- follows a pattern which remains specific to the level of the school (primary as opposed to secondary), the number of teachers involved (one as opposed to several) and the involvement of school administrators. The typical primary school uses the microcomputer mostly for drill-and-practice and remedial work, with a shift towards computer programming and computer literacy as more equipment becomes available. The typical secondary school uses microcomputers mostly for computer programming.

135. Resource constraints seem to have a different impact on primary and secondary schools. In the former, usually underequipped as compared to the latter, the equipment available is more evenly distributed across the school population. More microcomputers means here more children with access to them. In secondary schools, access is strongly skewed in favour of "programmers" as opposed to "drillers". Furthermore, an increase in computers results in increased time per student, rather than increased students per machine. In both elementary and secondary schools, the shift of initiative and control from the single enthusiastic teacher to a group of teachers and to school administrators correlates with a more even distribution of user time and type of use of the microcomputers.

136. Basically, similar evidence emerges from other smaller-scale observations of Canadian (Logan, 1983) and French schools (Naymark, 1983), with the conclusion that "in general, the picture that emerges is one with a strong flavour of trial-and-error, with teacher practices changing as their experience with computers grows, as their students' experience grows, and as the teachers themselves grow older" (Logan, 1983).

137. In terms of learning processes, the observed dynamics seem to produce, in the opinion of teachers, an impact which is essentially social and motivational rather than cognitive. Teachers in the large-scale US survey confirm some of the anecdotal evidence reported before in this report, namely that micros have led to increased student enthusiasm for schooling; to students working more independently, without assistance from the teachers; to students helping one another and answering each other questions; and to students being assigned to do work more appropriate to their achievement level. Other smaller-scale studies tend to confirm the teachers' perception of classroom changes. Regular use of computers in their classroom -- they say -- has caused their style of teaching to change from teacher-centred to student-centred. The presence of the "computer-expert" students in the classroom has had the effect on the teacher's perception of students in general, to a more positive view of their capabilities (Miller et al., 1982).

138. The pedagogical approaches implicit in some of the classroom uses of microcomputers seem therefore to bear their fruits, at least at the social and emotional level. As more sophisticated evaluation methods become available, as understanding on learning processes increases and more elaborate software is produced it will be possible to ascertain the merits of the approaches on more cognitive grounds.

139. These results are encouraging. The trends, however, remain fragile. There are still too few computers per school, too few teachers trained to use them, too little time for students to spend with them. By January 1983, in all categories of US secondary schools, a majority had at least one microcomputer, about 60 per cent had two or more, only 40 per cent had five or more. At the same epoch, the majority of primary schools did not have any microcomputer, only 46 per cent of them had one or more. Elementary schools then had a ratio of 100-200 pupils per computer, with an average access time per pupil of about 15 minutes per week. The median student/computer ratio in junior high schools was 181 : 1, the ratio went down to 88 : 1 for the best equipped secondary levels and the combination junior/senior highs. This means that the median of secondary school students using micros in a week ranged from 10 to 20 per cent, with a median of about 12 hours of use per week per student user. As for the teachers in about half of the schools with micros, only one or two teachers at most were found to be regular users (CSOS, 1983 and 1984). In Canada by the end of 1983, there was approximately 1 micro-computer for each 250 pupils (Crossley, 1983). The situation in other countries is no better, and often far worse.

140. The above figures indicate clearly that the introduction of the NIT in ordinary schools is only starting. By that, these figures suggest caution against too hasty a generalisation of the preliminary results available. But the trends observed suggest also encouragement to continue. The NIT do hold a potential for education worth exploring, worth investigating via research, experimentation and plain practice in the classrooms. The fact that they might be beneficial to learning makes it all the more important that the clientele should be large and include all levels of schooling, all types of schools and all pupils, without distinction of social class, origin or sex.

EQUALITY ISSUES

141. Twenty odd years of studies on "equality and inequality" have established a fine mapping of the processes involved, have thrown light on what rules govern the game. In all Member countries educational expenditure per capita increases with the level of schooling. The resources available for education resemble very closely the socio-economic mapping of the areas served by the schools. The socio-economic profile of students' prospects at the outset of their educational careers resembles closely that of their family of origin, the generational matching reproducing both the class and the sex affiliation.

142. It would be naive to expect that a single innovation, such as the introduction of the new information technologies in the school, could alone dismantle what a century of educational policies and practices have been unable to make a dent in. Yet the awareness of the limitations of the cure should not make us reject its possible merit. Otherwise, left to its own dynamics, the introduction of the NIT in education could very well increase the differences, as some of the evidence shows already.

143. A discrimination by level of schooling is at work in almost every Member country. Secondary and vocational education receives better equipment, is equipped faster and with a larger variety of courseware. Primary education, which the learning sciences indicate unmistakably as the priority educational target in terms of cognitive development, are left systematically behind. Furthermore, most of the investment in basic education is going to remedial education in its latest years. One wonders at the possible savings in material and human resources if only the educational interventions were better targetted at the very beginning of the cycle...

144. The schools that could be defined as poor on former grounds tend to remain poor in technological terms. Unless specific public interventions are planned, as in some Member countries, the gap between rich and poor will grow only wider. The quality of the learning provided by the educational establishments will continue to reflect their status on the scale of privileges.

145. When the computers were introduced in the French upper secondary institutions on experimental bases, the evaluation of the outcomes included positive elements as well as less positive ones, including the real danger that the technologies create within the courses of study a new "royal line" for a new elite in the school population. Here the stakes at the basis of the familiar debate on the curricular status of "informatics" showed a different colour: in terms of equality, what matters is less its introduction as a separate discipline or as a subject integrated in other disciplines, but whether or not the new curriculum has a place on the agenda of the final examination. Here, almost inevitably, certification creates elitism (Naymark, 1983).

146. When the computers were introduced into US schools, patterns of inequality also emerged. Here, left to the initiative of single teachers, the NIT are often used to the benefit of the above average school achievers (CSOS, 1983 and 1984), when specific experiments have proven that most of the others can also benefit. Given the class bias in the two groups, one can only

fear that the saying might come true of "the middle classes learning to use a computer while the working classes learn to play video games". Without specific intervention to the contrary, patterns of inequality are only strengthened.

147. Although not many specific studies are available on the subject, evidence is also growing on sex biased inequality in the access and use of the new information technologies in schools. They amplify the existing segregation of lines by sex, when the NIT are introduced in the science rather than humanities lines. Given the uncertain (at best) correlation found between proficiency in computing and "maths" abilities, one wonders as to the pedagogical justificaton of the educational decision. A number of studies in the United States show how the perceived association with maths and sciences, together with the content of most software available, appealing to boys rather than to girls, are "scaring away" girls in much larger numbers than boys (Beyers, 1983). The fact that the levels of schooling where the technologies are introduced most are those where the sex biases are already deeply entrenched, namely the secondary schools, makes the forecast for technological sex biases in the population only more gloomy.

148. At the end of a section on "educational strategies" in relation to learning processes and the new information technologies, a number of considerations could be made, serving at the same time as a summary and as a reminder of the major issues at stake. Perhaps the most important one is on the very close link observed between the institutional management of learning and the management of the institution itself. It would be difficult indeed, in the analysis developed in the previous paragraphs, to separate the problems pertaining more specifically to the learning processes from those with a stricter institutional and corporate bearing. Learning processes do not take place in an institutional vacuum, nor do institutional changes.

149. Financial resources translate reasonably easily in equipment, teacher training programmes, computerised lessonware or research programmes on cognitive processes. The influence of financial factors on motivation, attitudes and readiness to change in the gatekeepers of the educational system is much less direct. Yet without such changes the other will not take place easily. The average school principal, the average teacher, the system as a whole have more than one legal way to oppose, transpose, filter and absorb pedagogical innovations. The history of education is not short of examples. The NIT can easily become an additional chapter in an already fat book.

150. The consequence on the learning processes, the modalities of the emerging pedagogical approaches need to be made clear and appealing to educators. Their educational advantages need to be spelled out in detail. The curricular implications need to be worked out, the boundaries between disciplines discussed, the organisation of the school and the school personnel redefined to everybody's satisfaction. The working agendas are not short of items. Carried out to its fullest implications the introduction of the NIT in education is nothing less than a revolution, as large scale implementation of modern pedagogy would have been if only it had been adopted.

151. Yet everything cannot be done at the same time. Reaction times of policy-making bodies or funding agencies are different from those of institutions, of researchers or teachers, organisers or curriculum developers. Priorities have to be established for the working agendas of the

partners concerned. Issues and problems have to be identified for immediate action; other reserved for further investments. In short, priorities for the future have to be established in terms of substantive work, of chronological perspectives. Before that, and perhaps more importantly in the uncertain area of the NIT, the criteria need to be established to select issues and to allocate them to the priority lists where they belong.

Section III

AGENDAS FOR THE FUTURE

> "The NIT can be regarded as a pair of spectacles through which the problems are defined, as well as what factors or dimensions are important in the problems, and eventually what the feasible solutions are. Learning and working with these glasses can radically alter the students' and the teachers' perceptions." (I. Ruoppila, 1983).
>
> "She stretched herself up on tiptoe, and peeped over the edge of the mushroom, and her eyes immediately met those of a large blue caterpillar, that was sitting on the top with its arms folded, quietly smoking a long hookah, and taking not the smallest notice of her or of anything else." (L. Carrol, 1869).

152. This chapter is on the working agendas to draw in order to answer the many questions raised in this report as to the impact of the NIT on learning processes in formal education. Its based assumptions, as discussed before, concern the nature of learning -- a multifacetted process depending on the learner's abilities and motivation, on the specific technological supports in the learning environment, and on the influence of a network of active agents external to either of them, the power relationship among these influencing factors -- shifting according to learning situations; the specific role of the educational institution in transmitting knowledge and skills to the learners while safeguarding its own institutional interests, and finally the nature of the new information technologies, which keep diversifying and changing.

153. This multitude of factors and actors determine to varying degrees, what is learned, how and to what purpose. It means also that, depending on the "determining agent" considered, not one but several working agendas can be drawn to answer the same questions on learning each responding to specific and, to an extent, independent, interests and concerns. The remainder of this section will discuss some of the ways whereby the issue of learning and the NIT can be approached in view of establishing working agendas for the future. It will show some likely alternatives, the work priorities which could emerge, and the ways in which these could be met. More specifically, this section argues that separate approaches could be developed on similar "learning" issues reflecting the interests of cognitive sciences, or of pedagogy, of the institution of education, of social and economic concerns. It then suggests

what the criteria could be to select within approaches and discuss some of the likely consequences for the overall integration of the NIT in education.

AGENDAS

The "cognition" agenda

154. As it emerges from the previous sections, the impact of the NIT on learning processes can be analysed in a number of ways. One of them is to say that the NIT can facilitate the acquisition of knowledge and skills, have unforeseen effects on what is still unknown on learning and, finally, be used to understand the processes themselves. The dual potential role of the NIT as "revealers" and "analysers" of learning processes has emerged forcefully from the analysis developed in this report.

155. Within this broad context, specific issues have emerged for research on cognition. They could be classified in their turn under three main headings concerning the impact on familiar learning processes, the identification of the cognitive processes most especially sollicited by the NIT, and the consequences for learning of having the NIT as its main support.

156. Under the first heading one would list issues related to the time organisation of learning, such as its acceleration, or its sequential organisation, as well as issues more directly relevant to developmental models of cognition. Possible lists under the second heading would comprise research on specific learning processes such as on strategies of thinking, learning problem solving and concept formation as well as topics on information processing such as orientation, anticipation, cue-selection, perception, recognition, short- and long-term memory processes. An important place in this list would be devoted to the study of the cognitive benefits of learning computer programming and especially of its transfer value.

157. The third heading would cover more specifically concerns that could be called "existential". On this list one would include research on the effects on learning of looking at "reality" through the technological glasses, on the consequences for learning of the specific motivational and attitudinal factors triggered by the presence of the NIT in the learning environment, on their impact on interpersonal behaviour as well as on personality development. An important place in this list could be devoted to the impact of the NIT on the balance between "algorithmical" thinking as opposed to creative or lateral thinking.

The "pedagogy" agenda

158. A pedagogue concerned with the impact of the NIT on learning could draw a list from a different perspective. Its general guideline would be the assumption, developed in the previous sections, that the most promising role of the NIT in pedagogy is as "translators" of established cognitive and pedagogical thinking in models to be used currently in pedagogical practice at

affordable cost, and as "evaluators" of the effects on learning.

159. At the core of possible lists under this heading one would find the development of "real time" monitoring and evaluation techniques, of models of independent learning, of automatic assessment of errors, of rapid diagnosis of the profile of learning aptitudes. In other words, in this list the pedagogue's list would include the development of NIT-based applications of innovative pedagogical methods. Given its cost-efficiency, additional connotation of this list would also include specific considerations of the hardware requirements for desirable pedagogical objectives and their cost implications.

The "education" agenda

160. The inclusion of economic concerns on the working agendas is a clear indicator of a main pre-occupation of this report, namely that the impact of the NIT on learning be considered as something more than as an object of academic enquiry, or pedagogical modelling: that the possible benefits or shortcomings of the technologies for learning be considered not only in their own right but also, and foremost, in view of their possible applications to large-scale education.

161. This means that the working agenda drawn for education would include specific items related to the large-scale introduction of NIT-based learning methodologies in the familiar school settings. An important item on this list would concern the effect on learning of transferring experimental learning methodologies to ordinary school situations. The list would also include items concerning the impact on NIT-based learning of organisational variables such as the organisation of the learning environment in schools in terms of time, space and human interaction with other learners as well as with the teacher. An additional item would concern the analysis of the impact on learning of teaching practices that use the computer as a support alongside other supports without giving it the most prominent position.

162. This list is concerned with the reality of schools would involve the inclusion of other items concerning the ordinary school population as well as the established school curricula. On the former front, the list would include items on the personal profiles of the learners, in view of identifying the traits of those who learn best with the NIT and the reasons why. On the latter front, the items would include the development of curriculum prototypes, whereby the benefits of learning with the NIT could be insured and/or safeguarded in new curricular organisations of known or new disciplines. In particular, this list would give much space to the applications of the NIT to the acquisition of basic skills, such as reading, writing and numeracy as well as the development of new curricula centred on NIT-related knowledge and skills, aimed at achieving specific cognitive gains.

The "special population" agenda

163. The teaching-learning methodologies at work in formal education do not produce the same learning benefits across its population. Similarly, the NIT do not seem to have the same impact on all learners, with the patterns of differences in the two cases being not necessarily similar. A working agenda

built on the learning needs and possibilities of special education groups would respond to social and political concerns that are central to education.

164. Items in this list would include the study of the impact of the NIT on learning disaggregated by types of school learners. It would tackle the equality issue by studying the impact on boys and girls, the assessment of possible differences therein and of their personal and environmental determinants. Another section of ths list would concern the group of the low achievers and the impact of the NIT on their learning. Another set of items could address the learning needs of the handicapped. Yet another could consider the educational problems in sparsely populated areas and the ways in which learning by the NIT and especially distance learning could be of benefit.

The "manpower" agenda

165. Among the objectives of education, an important one is to educate the future manpower. A working agenda in this area would cover older learners, young people and adults and would be concerned with the specific learning processes of this older population.

166. A number of candidates for further investigation have emerged from the analysis developed in this report. No doubt many others could be also identified. Possible items in this list could include the impact of the NIT on the acquisition of knowledge and skills by novices or experts, the impact of established learning habits on the speed of acquisition of new ones, the specific role of the NIT on learning specific skills in training or retraining of manpower. In other words, the central theme of this list would be on the ways whereby the NIT could be used to make the acquisition of specific knowledge and skills by older learners more efficient on a cost/benefit basis.

SELECTION CRITERIA

167. Together with the development of working agendas, the future of learning and the NIT will be determined by assessing the wisdom of choosing one agenda instead of another. Besides the differences in their constituent items, thus in the specific publics addressed, the agendas developed before differ in other important respects, which are worth defining.

168. As discussed at the beginning of this report, the issue of learning and the NIT cannot be considered in abstract, as if learning occurred in a social vacuum. The active agents influencing what is learned, how and to what purpose are several. Their impact is of a different nature, follows different strategies and aims at different objectives. The introduction of the NIT in the fields of learning and education has implications for all the factors and actors concerned. The specific areas where future efforts will be concentrated will be identified and selected according to criteria which will inevitably reflect the different interests and priorities at play. Some of the decision making could focus on pure research needs, others on more immedia[illegible]ffs for education, or on economic or market imperatives. Yet other [illegible]uld be based on chronological considerations, on how to achieve [illegible]ogress in the short possible time, while reserving a medium

or long-term perspective to commitments and investment that are not economically or politically justifiable in the short run.

169. The task of establishing and selecting among criteria would already be arduous in other circumstances. At present, it is made even more complex by reasons that are specific to the problems at stake. The crux of the matter is, once again, time. On one hand, there is an obvious and urgent need to invest in the area of learning and the NIT. The new information technologies, essentially micro-computers and particularly the least powerful among them, are entering the educational system in ever increasing numbers, and they are entering homes in numbers even larger. In the absence of action to the contrary, it is likely that bad habits will develop and consolidate in the school population, that the NIT will generate new forms of social discrimination that will reinforce the old ones, that expenditures in education or training would remain at unaffordable levels for the general economy. The situation clearly suggests urgency, but it also suggests caution.

170. In the historical development of the new information technologies, we are passing through that especially privileged early phase when most of the ground for future developments is laid down, often irreversibly. It is extremely important that now, rather than later, we establish as clear as possible a diagnosis of needs, problems and possibilities, and act accordingly. What we do at this stage will not be easily changed in the future. When considering the introduction of the new technologies in the formal educational system, and when considering research and development investments on learning, it is clear that in the implementation of the decisions taken there will be little space for "trail and error" strategies.

171. To have noticeable effects, the investments in resources, at all levels, are bound to be large. Past history teaches us that when large sums of resources are involved in setting up a new system, subsequent corrections are almost impossible to introduce. Large investments produce visible effects, but they also produce rigidity in the system and inertia towards modifications. The larger the financial investments in a system, the more costly the eventual adaptation to changes. The larger the number of people involved in the production process, the larger the production but also the more difficult the eventual modification of the production itself, should the need arise. Given the degree of ignorance we still have as to the likely deep effects of the new technologies on learning, and as long as this ignorance remains the only guide to important policy and research decisions, it is certainly hazardous, and rather risky to invest massively at the beginning, on the basis of choices and priorities that could well turn out to be premature.

172. The working agendas drawn in this section are only indicative. They are also exceedingly biased by the kind of hardware used in the research and experimentation and the basis of the data analysed. Computer technology evolves fast. Other information technologies might become available on a large scale. Different technologies, currently only marginal to education, or even new technologies could enter the schools of the future. With the evolution of the hardware configurations available, their impact on learning processes could also undergo significant changes, with them the longevity of the problems and issues considered in this report could also change, and the working agendas altered accordingly.

173. Yet, if we do not invest on a large scale in the present, we will not

have the body of information we need to take further decisions, we will not know how to best insure equality of opportunities, how to modify curricula for different ages of the school population or different courses of studies. The dilemma of initiating actions that are bound to generate gains and losses simultaneously is a very familiar one to policy makers. No doubt, the same care will have to be used in the field of "NIT, learning and education" as has been the case for other educational transformations. In this respect, at least, the new information technologies have nothing new to propose.

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